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ABSTRACT

Described is the development of computer assisted learning packages for nonscience major undergraduate students. The equipment needed to run the packages is described as well as the role and value of the packages. Several examples of the kind of computer graphics used in the computing laboratory are illustrated. The problems associated with the packages are evaluated, and an assessment of students' work is given. (SA)

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VIBRATIONS AND WAVES : USING COMPUTER ASSISTED LEARNING

by

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1. Introduction

Much work has been done in the development of Computer Assisted Learning Material for physics teaching.[1-3] With the development of the CUSC* project, several computer assisted learning packages were produced at Surrey and incorporated into a Vibrations and Waves course for Chemical Physics students during the last four years. A "package" consists of a written student guide similar to that of a laboratory worksheet: and an interactive computer program. A detailed example is given later in this paper.

Because of the computer's ability to calculate complicated mathematical expressions rapidly, students can be provided with solutions to equations for physical systems which were once outside the scope of their course. They are able to choose their own parameters and to be provided with a wider range and more convincing examples than would be possible by any other method.

Solutions to equations using numerical methods rather than analytical, particularly if displayed graphically, can provide a greater understanding of the physical meaning behind mathematical equations. This enables the weaker students to gain some insight into the mathematics of a physical system without being restricted by their limited mathematical background.

In the Vibrations and Waves course, there are many repetitive calculations which are well within the ability of the students but are lengthy and tedious to perform. For example many problems in this area involve the summation of sines and cosines, which is not difficult but demands a large amount of the students' time. The speed of the computer eliminates

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* CUSC: Computers in the Undergraduate Science curriculum a project sponsored by the National Development Program in Computer Assisted Learning 1974-1978

the boring side of these calculations, enabling the students to concentrate on the meaning of the results they obtain. Figure 1 shows an example of a graphical display.

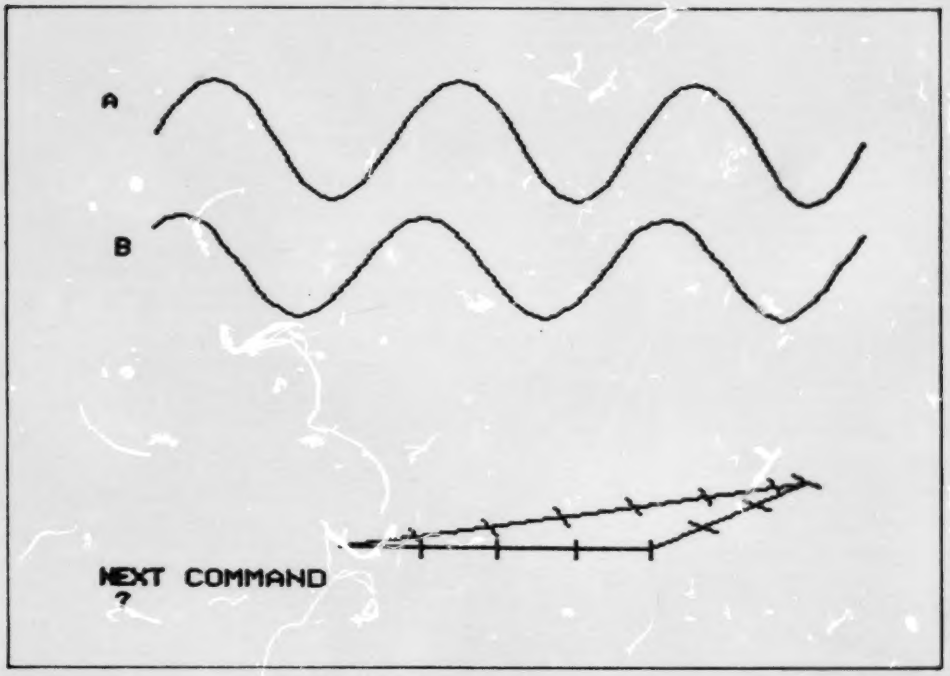

FIGURE 1

This display shows the phasor diagram as calculated and drawn by the computer which represents the amplitudes of two coherent waves, and their resultant, combined amplitude. The amplitudes and phase difference between the two waves are chosen by the student.

All Vibrations and Waves packages used in this course have graphical displays. These displays are useful in providing a picture which demonstrates the relative importance of the parameters governing a particular mathematical relationship.

2. Vibration and Waves in Chemical Physics

For the past fifteen years, "Vibration and Waves" has been part of the firstyear course in the Chemical Physics degree of the University of Surrey. This degree course was set up to provide a broad based academic training for students who wished to cover a wide variety of topics in their University Education.

It therefore seemed appropriate to expose these students also to Computer Assisted Learning and this now occupies one third of the fifteen hours given to the Vibrations and Waves course.

Many students in the Chemical Physics Department do not intend to become scientists, and combine the basic subject of the course, Chemical Physics, with other subjects, such as:- Economics, Science and Society, Government etc. The variety of subjects offered is likely to attract students from different educational backgrounds some of whom have an inadequate mathematical training for the University course they intend to follow. It is felt that Computer Assisted Learning can help such students to overcome some of their difficulties by giving them greater insight into the symbolism and meaning of basic euations.

3. Vibrations and Waves Packages

Five packages have been used by the students during their Vibrations and Waves course:-

Energy of Simple Harmonic Motion
Combination of Two Oscillations
Phasor Diagrams
Quality Factor
Forced Oscillations

A package consists of a student guide and a computer program. The guide provides an introduction to the subject, background information on the theory and structured notes which enable students to interact with the computer.

Students are expected to have had lectures or tutorials on the particular topic before coming to the computing laboratory. All the Vibrations and Waves packages have questions incorporated in the guide which can be answered with the use of the computer programs.

The programs are designed to provide the maximum amount of interaction between students and the computer to encourage active participation by the students in the topic they are studying. For example:- the package on the combination of two oscillations is concerned with the combination of two equations representing two simple harmonic motions. In the first part of the package students are required to insert values of the amplitude A and frequencies n_1 and n_2 of the two oscillators where the equations of motion are given as:-

$$X_1 = A \cos 2\pi n_1 t$$
$$X_2 = A \cos 2\pi n_2 t$$

Combination of these oscillators produces a resultant displacement of:-

$$X = 2A \cos(n_1-n_2)\pi t \cos (n_1+n_2)\pi t$$

Students are told to find suitable frequencies which would produce beats for the combined oscillation. The graphics display (Figure 2) shows clearly the effect of choosing frequencies very different from each other, for example $n_1 = 2n_2$, the combined oscillation shows harmonic overtones

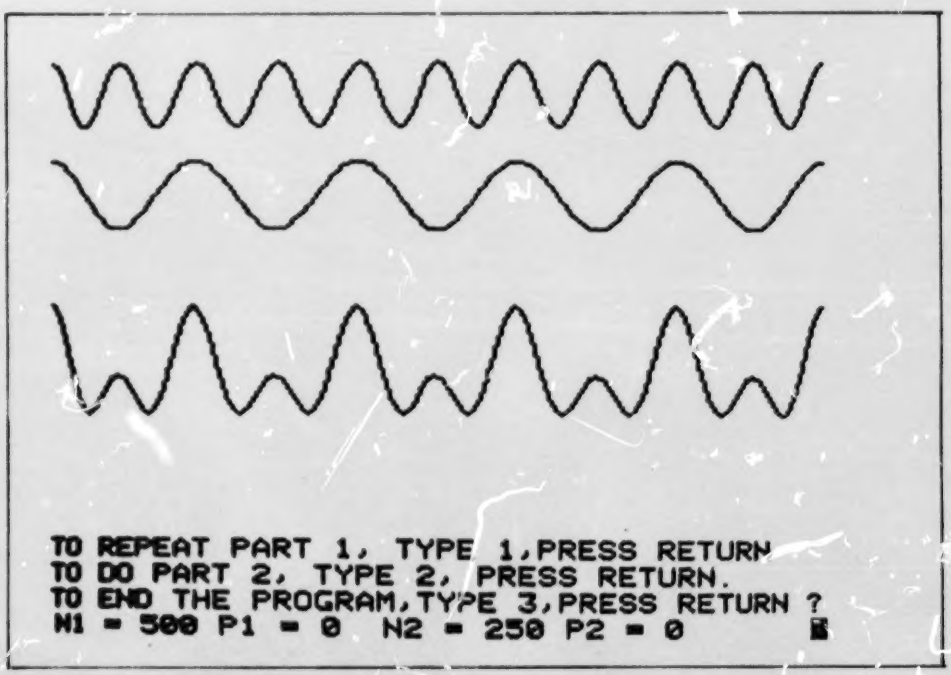
TO REPEAT PART 1, TYPE 1,PRESS RETURN
TO DO PART 2, TYPE 2, PRESS RETURN.
TO END THE PROGRAM,TYPE 3,PRESS RETURN ?
N1 = 500 P1 = 0 N2 = 250 P2 = 0

FIGURE 2

The students discover that beats are only obtained if the frequencies are similar (Figure 3)

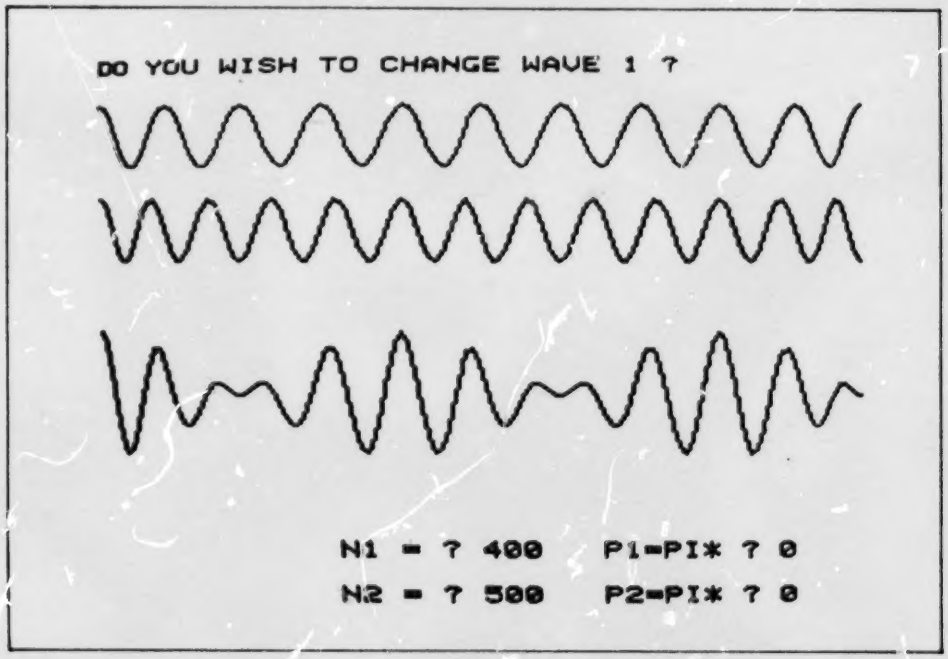

FIGURE 3

In the second part of the package the students can study the effects of two oscillations acting at right angles (Figure 4).

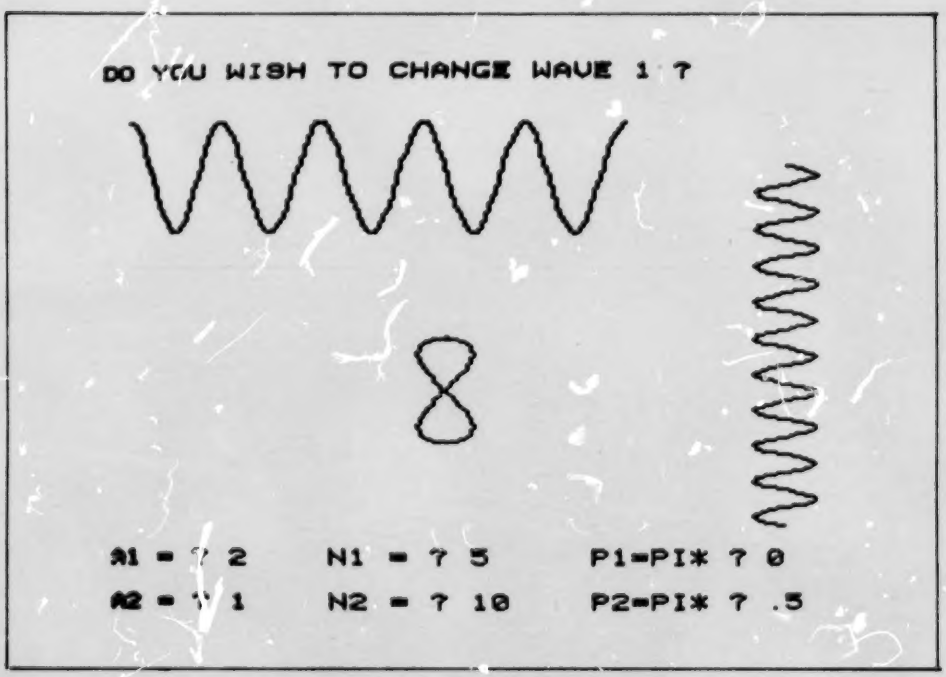

FIGURE 4

This is very similar to a physics practical where one can do the same sort of study using an oscilloscope, but has the advantage of not requiring any special extra facilities (apparatus) or setting up.

In the educational establishments which may be short of trained laboratory staff and suitable equipment, a wide range of simulated experiments can be carried out on the computer. This involves a once and for all expenditure on computing equipment which may also be used for many other purposes.

The educational aim of each package is to involve the students in an interactive role with the program to stimulate their interest and deepen their understanding of the topic. In the first year of their use they were included as part of a self-paced course[4] available to students as they reached the particular course unit. More recently they have been used in a class situation similar to a laboratory session.[5] In either teaching situation, CAL packages can be designed to cater for mixed ability groups by having an open ended structure to them.

The packages have been found useful in three respects:-

a) To supplement the lectures, particularly where this would involve a lot of blackboard sketches.

b) To extend lecture material by more detailed and varied numerical examples.

c) To give students an opportunity to test the equations with various numerical values, with a different approach from laboratory or conventional tutorial methods.

4. Hardware

4.1 Terminals

The programs used by the students are available on

three kinds of graphics terminals:- Computek 300 Raster Scan terminals, tetronix 4010 direct view storage tube terminals, and Newbury-Graphics Option Controller Terminals which also have a raster scan. Both the computek and Newbury terminals have selective erase facilities which enables the user to erase part of the display and detain the rest. All three have read cursor facilities which allows the user to move the cursor around on the screen and either draw pictures or diagrams from the keyboard or read off co-ordinates from the keyboard. The Newbury terminals have the added advantage of having roll up alphanumerics which can be superimposed on a graphical display, which in turn includes an independent set of larger characters in the graphics store for labelling graphs and diagrams.

The Tetronix has a better resolution than the other two terminals but has the disadvantage of no selective erase and poorer visibility of display.

4.2 Computer

Initially the packages were run on a Nova 840 which has a time sharing system and uses extended BASIC. In general the terminals are run at 1200 baud (120 characters per second) which is necessary for producing a fast graphical display. The University of Surrey has a Prime 400 (which is being updated to Prime 550) has both Fortran and Basic languages. Both these computers are Mini computers which can support between 20 and 40 terminals on a time sharing system. We also now have a Z2 microcomputer with 32K memory which supports one graphics terminal at 1200 baud and stores the programs on disquettes in Basic. With additional circuits the Microcomputer should be able to support four terminals for a small extra cost. With the explosion of microprocessors CAL will be available to many academic institutions who previously have been financially unable to take advantage of such a facility. This microcomputer, together with a Newbury/GOC is

is available to the conference to demonstrate CAL material.

5. Evaluation

The packages have been evaluated[6] by means of observation schedules and student interviews. These revealed organisational problems and also helped to show the most useful aspects of CAL

5.1 Organisational points

a) Overcrowding at the terminal. Half the class attended the laboratory at the same time which meant that students had to sit up to four at a terminal. The number of terminals now available has been increased and the number of students at a terminal has been reduced to two.

b) Distribution of student notes. The students did not always receive the notes sufficiently ahead of time. Because of their weak scientific background it was found that many students needed to rely heavily on the notes. These guides are now distributed to the students at least a week ahead, to give them time to prepare for the session at the terminal, and to clarify the relationship between the packages and the rest of the course.

c) Time allotted was too short. Most of the packages are now finished within the time allocated. This is helped by earlier distribution of the notes.

d) Infrequent visits. Some students felt that coming only once every two weeks was too infrequent. This was unavoidable as the schedule depended on many other timetables due to the varied nature of the degree course. Some students came to extra sessions in their own time.

5.2 Educational advantages

General educational advantages which became apparent related mainly to processes which the students underwent, and not to products, ie anything in particular that they learnt.

a) Interpreting. Students working together in pairs were led to discuss the interpretation of the graphs plotted on the screen.

b) Experimenting. The student notes were sufficiently open-ended to allow students to decide for themselves the best strategy to use.

c) Reasoning. Students found they were often forced to think about the theory in order to explain why they obtained a particular result.

d) Visualising. Packages provided an alternative form of visual representation which students found useful.

6. Assessment of students work on the CAL packages

The students were expected to return their guide, with the completed problems, to be assessed as part of their coursework. From previous experience of not assessing the students work[7], it was found that assessment acts as a powerful incentive to the students

a) To attend the laboratory sessions

b) To complete the work by submitting the guides for assessment.

Many of the students following the course are not highly motivated and find the degree work hard and demanding. This is apparent in the results obtained in other parts of the degree course. Continuous assessment gives encouragement to the student and a guide to the teacher on the students' progress.

In the first two years one of the examination questions was based on the teaching done in the CAL laboratory. It was found that on both occasions very few students

attempted the question and those that did were not very successful. The reason for this may well be that the CAL experience was mainly concerned, as mentioned above, with processes, while what students are tested on in examinations is what they have learnt, ie products. However, the course work marks obtained in this part of the course proved to be a fairly accurate forecast of the written examination results, more so than conventional tutorial course assessments.

7. Conclusions

Experience with conventional written examinations has shown that, although the CAL course does enable students to visualise the equations better than the standard tutorial, the experience with CAL does not assist them in answering standard examination questions.

It appears that the type of insight given by CAL into mathematical physics, such as Vibrations and Waves, is of a different character from that obtained from a conventional lecture course, and changes must be made in the method of examination, and possibly also in the lecturing and practical work when CAL is incorporated into a conventional teaching course.

The ways in which CAL does help in the teaching of Vibrations and Waves can be summarised as follows:-

a) Widening the scope of the subject by helping with complicated calculations

b) Increasing the understanding of the student by providing physical meaning to the mathematical equations

c) Removing the tedium from repetitive calculations.

d) Helping the students to visualise equations

e) Encouraging the students to interpret the graphs produced on the screen

f) Developing the reasoning powers of the students

g) Providing experimentation within the subject.

Although the CAL Sessions are not a replacement for tutorials, they can provide a very useful educational method for teaching and in some instances can also be used as a substitute for laboratory work where experiments are too costly or dangerous to be avilable in the laboratory.

Where there is a shortage of skilled laboratory technicians or suitable laboratory equipment, a wide range of simulated experiments can be carried out. This may be very suitable for developing countries.

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